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PASSIVE DAMPING CONCEPTS FOR SLENDER COLUMNS IN SPACE STRUCTURES

By

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A. FURTHER PASSIVE DAMPING EXPERIMENTS

Research into the identification of potential passive damping concepts for use in very slender structural members is continuing. The following damping concepts are under current investigation:

1. Mass-String Dampers
2. Bright Zinc Chain
3. Polyethylene Tubing
4. External Viscoelastic Tape
5. Brushes for Electrostatic and Frictional Damping
6. Suspended Chambers with Oil and Discs
7. Hybrid Concepts

Extensive testing of the first three concepts already has been conducted. Experiments are presently being carried out for the 4th and the 5th concepts. A comprehensive research report embodying the experimental results and theoretical comparisons for the first three damping concepts is being prepared and will be ready in March, 1985, for an initial review. A brief description of each of the seven concepts, and an outline of the results obtained for the first four concepts, are given here. Each of the tests was conducted on a partially restrained tubular member 12 ft. long, as used previously for this research project. For each test conducted, the member was initially plucked at mid-height by 0.366 in. and then released to induce natural vibration. The damped natural frequency for all the cases was observed to be generally about 3.8 Hz experimentally while that found

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from Eq. 28 of the NASA Memorandum was about 3.7 Hz with a rotational end spring stiffness, $\bar{K}$, of 2,230 inch-pound/rad.

1. Mass-String Dampers

The concept of lead masses attached to a strip suspended inside the tubular member as described in NASA Technical Memorandum 85697 has been explored extensively. Specifically, the influence of the number of lead shots, and connection friction on damping is studied. Figure 1 shows two curves for damping ratio, ζ, versus the number of lead shots, N, with and without jam nuts, respectively. The lead shots are suspended at member mid-height and attached to a nylon string next to each other. The nylon string is attached at the top of the tubular member internally. The jam nuts are used for a considerable reduction of connection friction. As is evident from these curves, the presence of jam nuts results in a reduction of the damping ratio. For example, with a total of 15 lead shots, the value of ζ with jam nuts is about 86% of its value without jam nuts. Approximately, the same difference holds for all other N values. For N = 21, the value of ζ is 0.0060 with jam nuts. The corresponding experimental deflection-time plot for this case is shown in Figure 2.

In the experiments with N = 21, the value of ζ was found to vary slightly with time. This variation diminished as a decreasing number of lead shots was used.

2. Bright Zinc Chain

A "bright zinc chain" weighing 0.05 pound/foot was suspended inside the tubular member by a nylon string to absorb the vibration energy through collisions as well as frictional forces between the chain links. Chains of 1, 2, 3, 5, 7, 9, and 10 foot lengths were tested. Each chain was situated symmetrically about the member mid-height. Natural vibration tests were conducted in the presence of end jam nuts. Figure 3 describes a typical deflection-time plot with a 10 foot long chain. This figure shows that the motion of the tubular member is completely finished within about 7 seconds.

A noteworthy characteristic of the chain damping approach is that the ζ values obtained from it increase considerably with time as the chain length is increased, unlike the mass-string concept in which ζ remains constant. Figure 4 shows the time-dependence of ζ for various chain lengths in the form of ζ versus average time curves for chains of various lengths. Each of the curves in this figure is plotted by using the ζ values computed from the experimental deflection-time relationships for an average time, t_a, of 0, 1, 2, 3, 4, 5, and 6 seconds, respectively. It is clear that the ζ values increase rapidly both with an increase in the chain length as well as the time of vibration. The best results are obtained for the 10 foot long chain for which ζ increases with time almost exponentially.

3. Polyethylene Tubing

Three different types of polyethylene tubes were used for damping by insertion into the tubular member for the entire length. One set of tests was conducted with a polyethylene fumed tube with an outer diameter of 0.33 inch approximately. A second set of tests was conducted with a less stiff polyethylene tube with the same cross sectional dimensions. The third set of tests was conducted by first inserting a low stiffness polyethylene tube (outer diameter = 0.25 inch, wall thickness = 0.04 inch approximately) into the fumed tube, and then inserting the resulting assembly into the tubular member under test. The second setup gave the maximum amount of damping compared to the other two polyethylene tube setups, with a ζ value of 0.0023. This system, therefore, did not prove to be as effective as the mass-string or the bright zinc chain damping systems.

4. External Viscoelastic Tape

A one-inch wide paper-thin viscoelastic tape was mounted on the external surface of the tubular member over its entire length. The tape was first spiral wound around the member and then the whole assembly was placed in a temperature-controlled heating system, and heated to 200°F for about five minutes. The procedure was suggested by the manufacturers of the tape but appears not to have worked well in this case. This is because certain portions of the tape appeared to have become somewhat overheated and embrittled. The maximum ζ value observed was nearly 0.0018, with a frequency of 3.60 Hz. Further exploration of both external and internal damping treatments is necessary before arriving at any conclusive decisions.

5. Brushes for Electrostatic and Frictional Damping

A major problem faced in electrostatic and (unavoidable) frictional damping concept has been the identification and selection of appropriate dissimilar materials for installation in the rather limited space available inside of the tubular member. Presently, two types of brush-type materials are under investigation. One of these consists of nylon fiber brushes (trade name: Quickie Percolator Brush manufactured by Quickie Manufacturing Corporation, P. O. Box 156, Cinnaminson, NJ 08077). Each brush is about 3.5 inches in length and can be forced into the tubular member and placed anywhere lengthwise by means of a nylon string. Several such brushes can be used at the same time to cover various lengths along the member longitudinal axis. The electrostatic and frictional effects due to the interaction of the brush bristles and the inside walls of the member may produce damping effects. A second material being considered is a "weatherstrip" used to stop window rattling (trade name: Pile Weatherseal manufactured by Elgar

Products, Inc., Cleveland, OH 44122), which is 0.25 inches wide, has 0.1 inch long hair-like synthetic bristles, and can be used in any length inside of the member. Presently, thin long brushes mounted on metallic or plastic stems are being sought which may be inserted along with the weatherstrip with interconnecting low-stiffness springs. The interaction of the brushes with the weatherstrip may provide the desired damping effects.

6. Suspended Chambers with Oil and Discs

Figure 5 shows a number of chambers with oil and thin copper discs suspended inside the tubular member by a nylon string. The effect of the number of chambers, oil viscosity, and the number of discs on damping will be investigated.

7. Hybrid Concepts

Besides carrying out a search for single damping concepts, combinations of the most promising concepts will also be tested. Figure 6 shows an example of a hybrid concept in which the suspended chambers with oil and discs are interconnected with chains.

B. NATIONAL SCIENCE FOUNDATION DYNAMIC EQUIPMENT PROPOSAL

A research equipment acquisition proposal titled "Dynamic Equipment for Space and Lifeline Structures" has been submitted to the National Science Foundation, Washington, D.C. in December, 1984 by Zia Razzaq and Leon R. L. Wang. A total of $93,387 has been requested from NSF (of which one-third cost will be shared by ODU) for the acquisition of devices needed to conduct passive damping tests on slender members for space structures as well as to conduct some earthquake engineering tests. There is a high probability of receiving this funding by June, 1985. If granted, a part of the funds will also be used to develop support-frames for mounting specimens for dynamic testing. This particular grant program of NSF does not provide any support for the graduate students or the principal investigator and is strictly restricted to research equipment requests on a highly competitive basis.

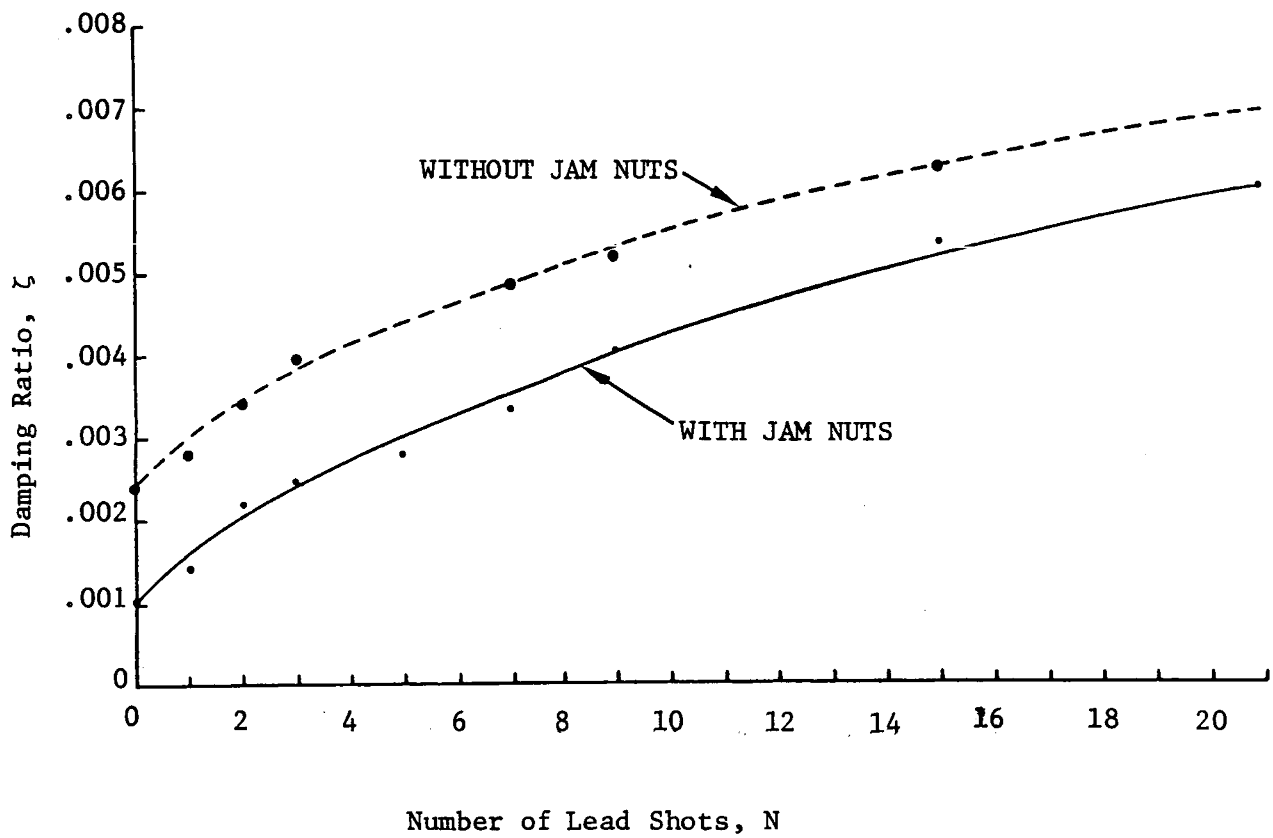

Figure 1 Effect of Connection Friction on Damping Ratio versus N relations

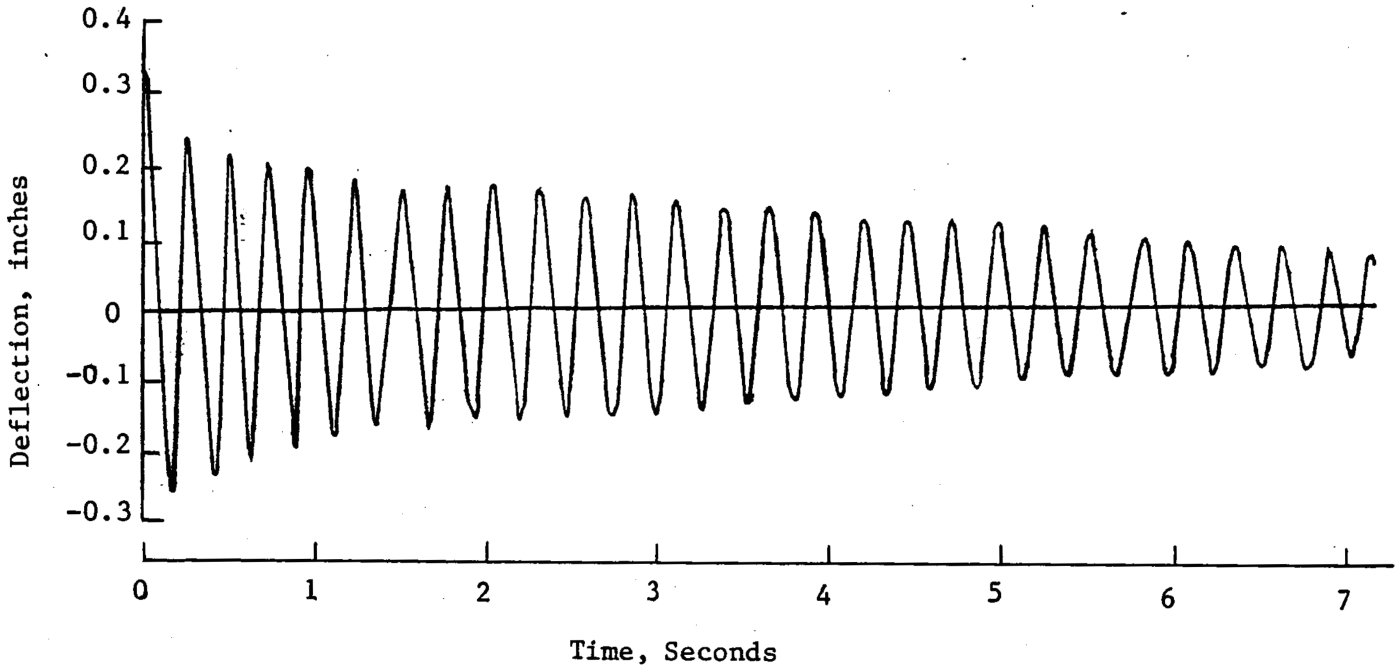

Figure 2 Deflection-Time Relationship with Mass-String System

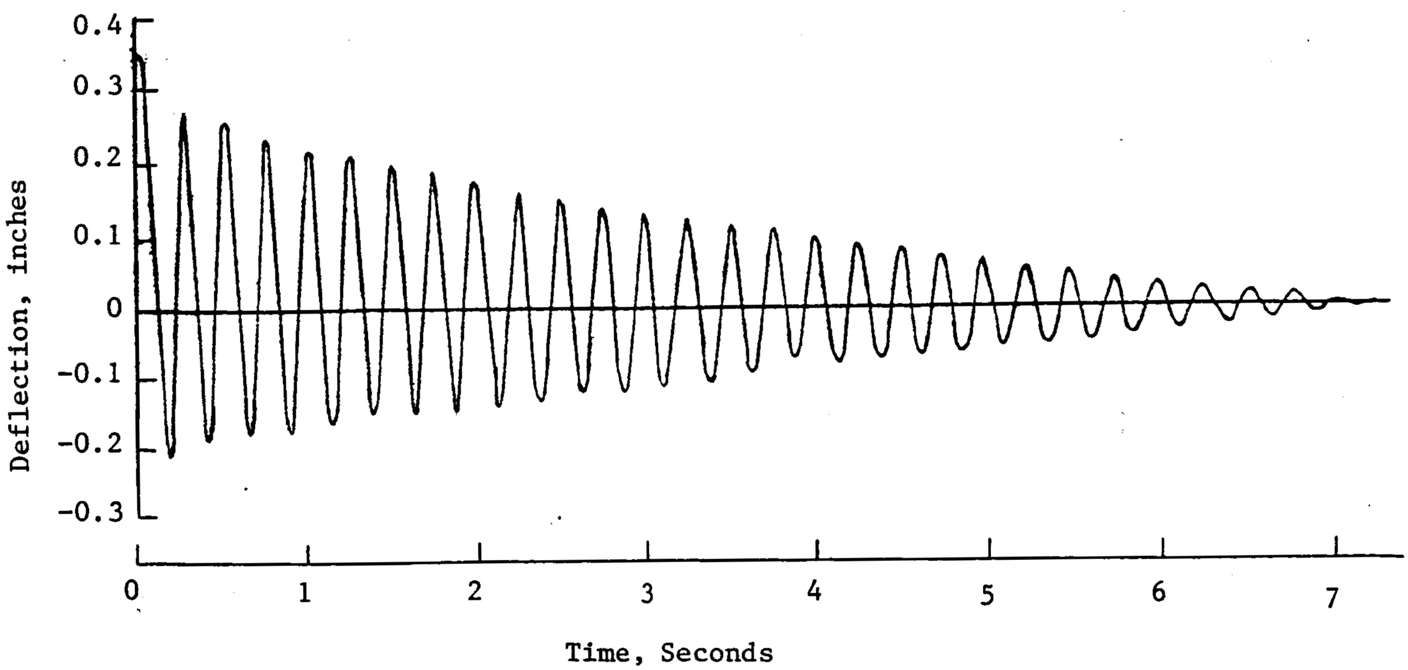

Figure 3 Deflection-Time Relationship with 10 ft. Chain

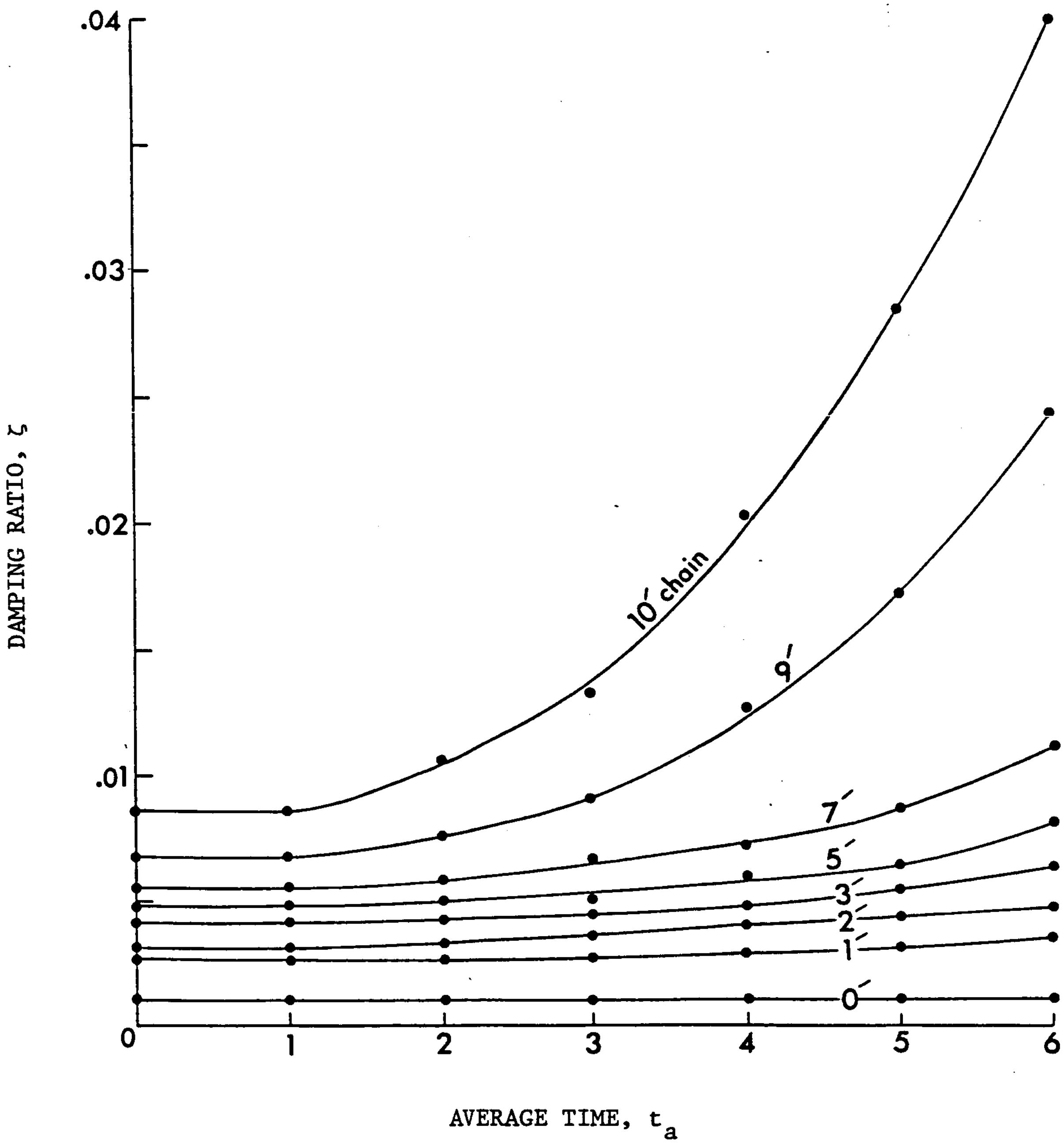

Figure 4 Time-Dependence of Damping Ratio for Various Chain Lengths

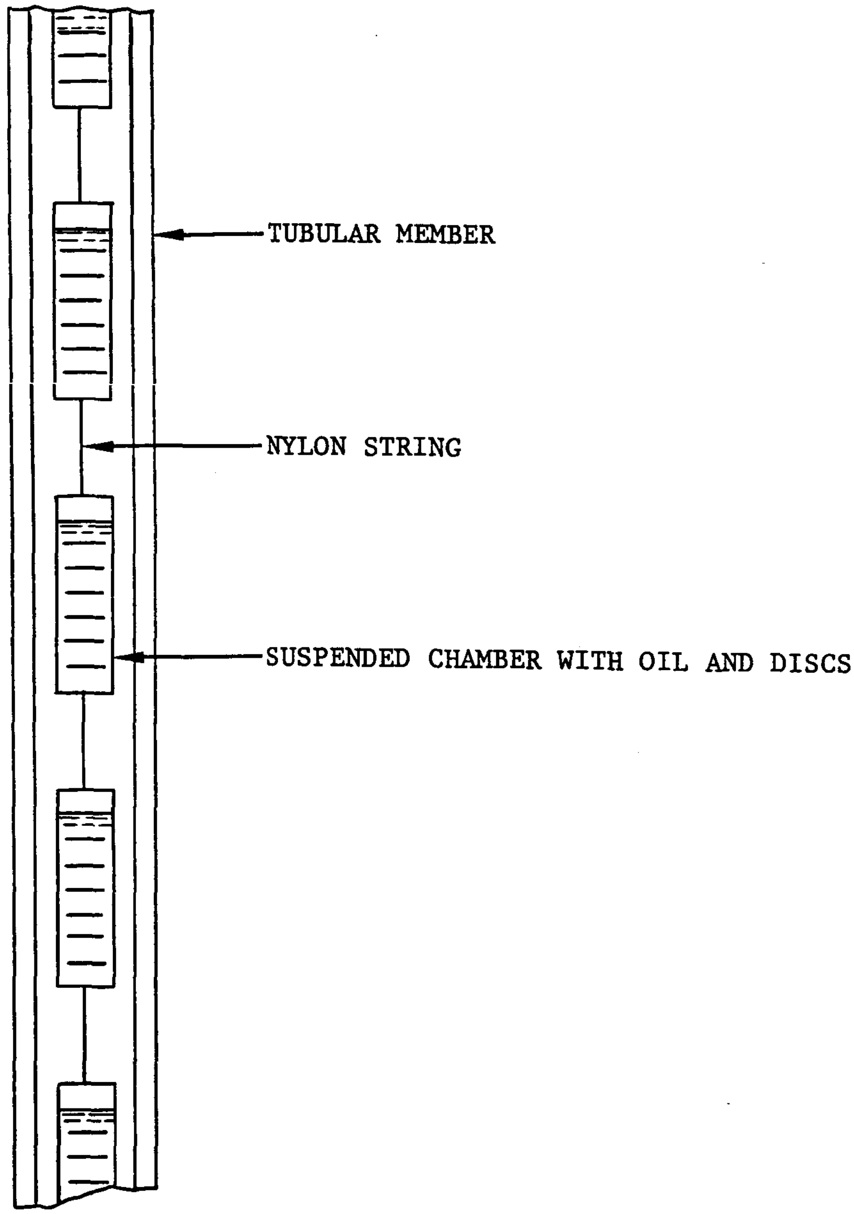

Figure 5 Suspended Chambers with Oil and Discs

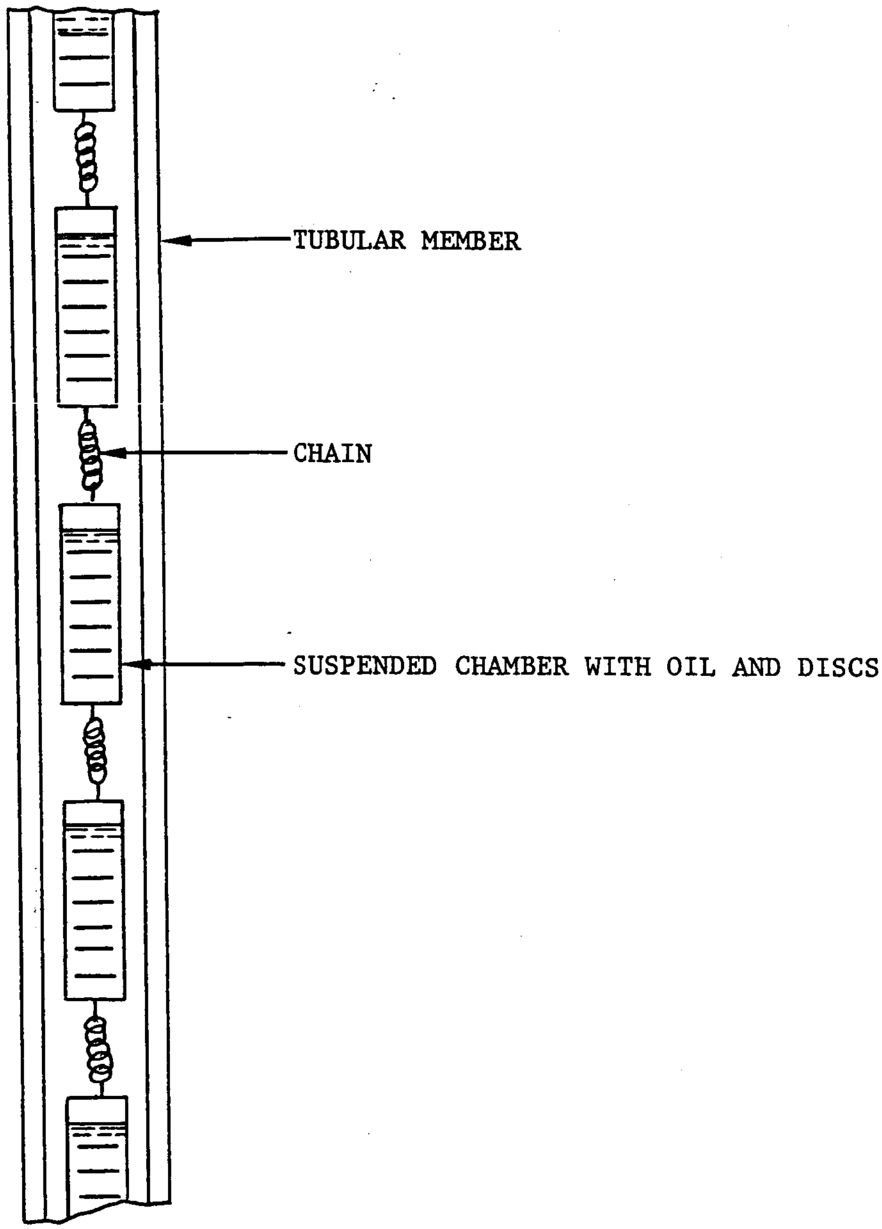

Figure 6 Hybrid Concept